Regional Research Laboratories, U. S. Department of Agriculture

W. B. VAN ARSDEL

WESTERN REGIONAL RESEARCH LABORATORY, ALBANY, CALIF.

R. K. ESKEW

EASTERN REGIONAL RESEARCH LABORATORY, WYNDMOOR, PA.

E. A. GASTROCK

SOUTHERN REGIONAL RESEARCH LABORATORY, NEW ORLEANS, LA.

C. T. LANGFORD

NORTHERN REGIONAL RESEARCH LABORATORY PEORIA, ILL.

The four Regional Research Laboratories constructed by the U. S. Department of Agriculture in 1940–41 contain areas designed for process research. During the past seven years these areas have been the scene of a wide variety of large scale developments. The alterations, improvements, and special facilities that have grown out of this experience are discussed. Limitations on use of a single general area for diverse operations are pointed out. The authors summarize their experience with problems in housekeeping and maintenance, and in making proper provision for comfort and safety of the staff.

THE four Regional Research Laboratories operated by the Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, were designed in 1938–39 and occupied during the winter of 1940–41. The laboratories are located in Wyndmoor, a suburb of Philadelphia; in New Orleans; in Peoria, Ill.; and in Albany, Calif., on the east shore of San Francisco Bay. All four follow a single general plan, with some important differences in detail. Four widely different research programs have been pursued. The present paper reviews the experience of the chemical engineering staffs with the physical facilities provided at these four institutions and summarizes the opinions of these engineers about the design and operation of process development areas for large research laboratories.

The regional laboratories were established in accordance with an act passed by Congress in 1938 for the express purpose of applying scientific and technological research to broaden the utilization of farm commodities. Although emphasis was placed on the discovery of new uses for farm products, the charter was broad enough to comprehend research on the improvement of established means of utilization. The act authorized the annual appropriation of $4,000,000, and successive Congresses have, except in one year, appropriated the full amount. This sum would, it was estimated, support at each laboratory a total staff of about 300 persons, approximately 200 of whom would be scientists and engineers of professional grade. The buildings were designed to house a research staff of that size.

The congressional hearings had made it plain that large scale commercial application of the research results was to be regarded as the criterion of success. Consequently, during the planning of the buildings heavy emphasis was placed on facilities for process development on the pilot plant scale. The Bureau of Agricultural and Industrial Chemistry had, for a number of years, conducted utilization research that was carried as far as the pilot plant; this experience was an invaluable guide. In addition, an extensive survey of existing laboratories was made during the early stages of planning.

From the first it was evident that no one plan for the pilot plant space would serve equally well for all four regional laboratories. The southern laboratory would be concerned mainly with research on cotton products, probably in the field of textiles. In the northern laboratory emphasis was to be laid on utilization of the cereal grains and therefore provision would be necessary for large scale fermentation and distillation processes. The major commodities assigned to the western laboratory—fruits, vegetables, and poultry products—made food processing the principal concern of that laboratory. No one field of work could be foreseen as predominating in the eastern laboratory, which therefore remained unspecialized in design.

GENERAL DESIGN OF PILOT PLANT AREAS

The regional laboratories are all four-story buildings constructed on the U-plan. The base of the U contains the administrative offices, one of the long wings consists of typical research laboratories, and the other wing comprises the pilot plant area. Differences in construction costs at the four sites resulted in some differences in the length of the side wings; at the northern and eastern laboratories the length is 256 feet, while at the western and southern laboratories it is 304 feet. The width of the wings is the same in all, 64 feet.

Because of the special differences in research programs referred to above, no two industrial wings are developed exactly

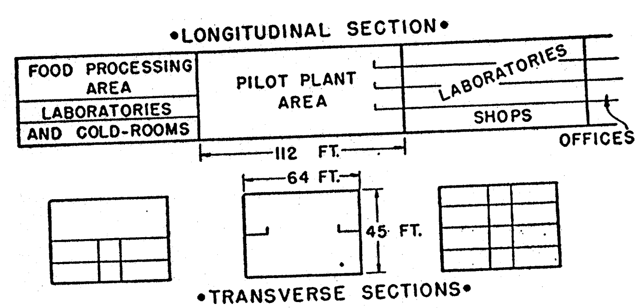
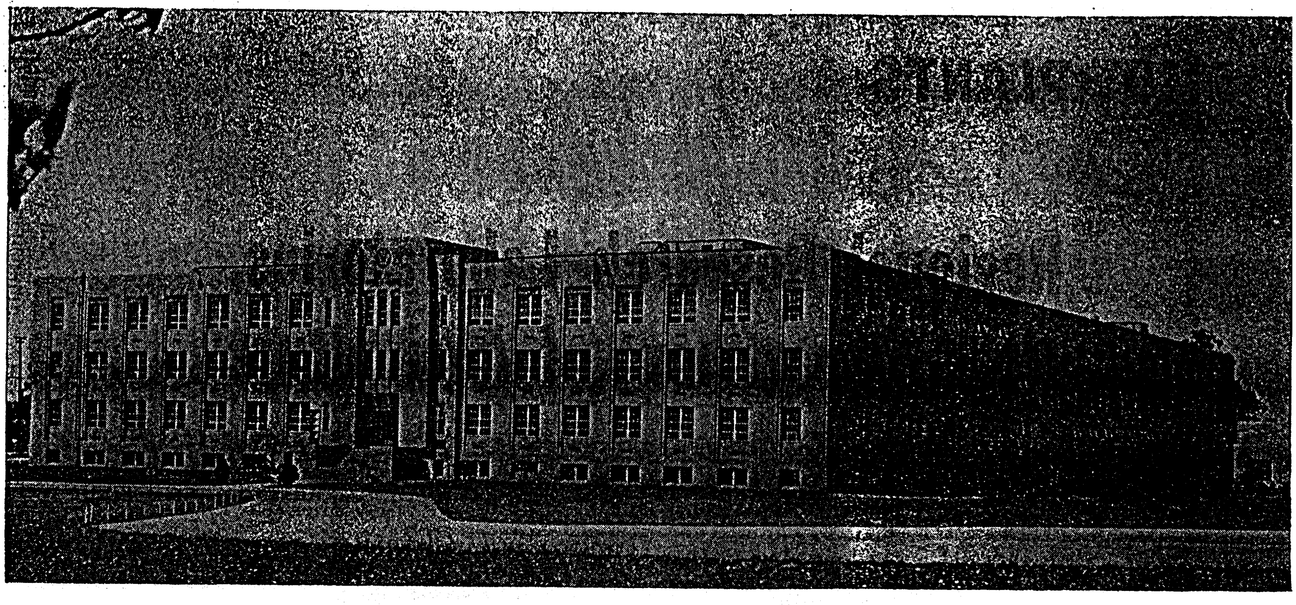


Figure 1. Diagrammatic Section through Industrial Wing, Western Laboratory



Western Regional Research Laboratory, Albany, Calif.

alike. All four, however, contain a large open area four stories in height, which measures about 45 feet from floor to roof beams. This, the "pilot plant area" proper, is the main subject of the following description. Its dimensions range from 112 × 64 feet in the western laboratory to 208 × 64 feet in the southern and eastern laboratories.

Figure 1 shows the general arrangement of the industrial wing in the western laboratory. The longitudinal spacing of columns makes 16-foot bays. Six of these bays next to the administrative office wing are developed as laboratories on three floors, with mechanical shops on the ground floor. The next seven bays constitute the general pilot plant area. The last six bays are developed with laboratories and cold rooms on the two lower floor levels, and a special large scale food processing area above them, open two stories, about 22 feet clear.

In the northern laboratory the space in the industrial wing partitioned off for use as an alcohol pilot plant is open four floors, except for the development of side and end balconies, and has a floor area of 80 × 64 feet. In addition, a separate specialized pilot plant building has recently been erected to house large scale experimentation on the production of motor fuels and other products by the hydrolysis of agricultural residues such as corncobs.

In the southern laboratory experimental textile equipment is installed on three one-story floors each 96 × 64 feet, and cotton treating equipment, including a kier boiler, a calendar, dryers, etc., is housed in another one-story space in the chemical wing, 96 × 26 feet. Figure 2 shows the padding machine, with the kier boiler immediately behind it.

CRITIQUE OF GENERAL DESIGN

After some seven years of widely varied operations, the engineering staffs of the four laboratories agree that the original design of the general pilot plant area provided an excessive amount of area with 45-foot headroom. For the great majority of operations 22 feet are ample. Plans are being worked out in the southern laboratory for installing additional columns and floors to give much more working area with 11- and 22-foot headroom, eventually leaving only a central well with the full 4-story depth; the floors within the well will be offset so that the crane can drop its load on any one of them. The original designers were wise in their avoidance of a rigid crystallization of the entire space; they did not overdesign. The modifications experience has shown to be desirable have been accomplished simply and economically.

Another lesson of experience is that distinctly different types of large scale development cannot successfully be carried on together in the same large room. This was partly recognized at the beginning when the alcohol plant was segregated at the northern laboratory and the textile mill at the southern. In the western laboratory, however, both large scale food processing and chemical process developments were for some years located

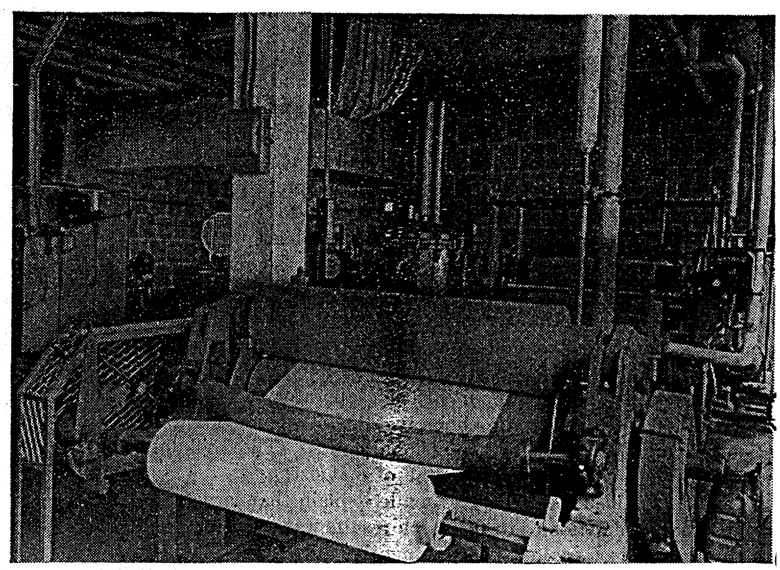


Figure 2. Cotton Chemical Finishing Equipment in Southern Laboratory

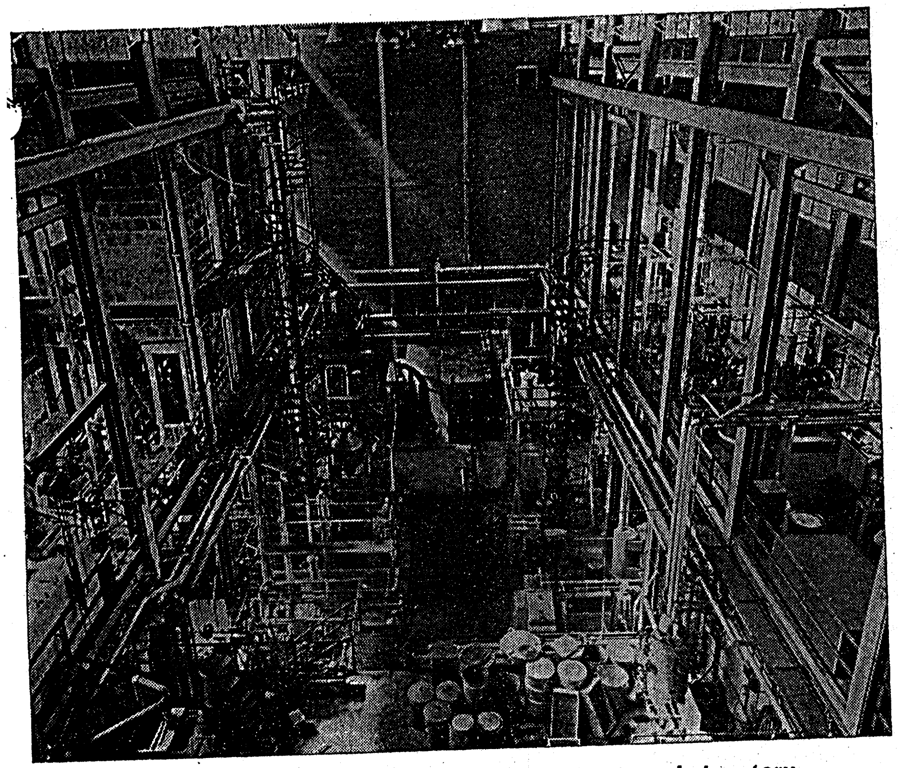


Figure 3. General View of Pilot Area, Northern Laboratory

in the general pilot plant area. This has been far from satisfactory. The design requirements for a good food processing room are, in fact, distinctly different from those for a chemical process room. The food processing laboratory must be built so that scrupulous cleanliness is not only possible but relatively easy to attain. Foreign odors, dust, and fumes must be excluded. The food processing area indicated in Figure 1 is being developed with these requirements a foremost consideration.

MECHANICAL DESIGN

The general pilot plant areas are constructed at ground level, with heavily reinforced concrete floors, and direct truck access through a roll-up curtain door. The vertical clearance at this door is 10 feet 11 inches, not quite enough to admit some large trucks. A clearance of 15 feet would now be recommended foı new construction. Twin rows of heavy free-standing columns, as shown in Figure 3, form a central clear space 35 feet wide and four stories high. The side spaces between the rows of columns and the walls are variously developed with permanent or temporary balconies. In Figure 3 an enclosed space on the left-hand balcóny may be seen; this is occupied by solvent extraction equipment which must be treated as an explosion hazard. In three of the laboratories the 35-foot span between the rows of columns is bridged by a 5-ton electrically operated traveling crane. This has been found to be extremely useful for unloading heavy equipment from trucks that are driven into the building, and for moving equipment from one location to another. The balconies are inaccessible to this crane, but a swinging jib crane mounted on one of the columns may be used for placing lighter equipment on the balconies.

Provision for the supply of utility services to these areas was given most careful thought. The characteristic service requirements were that the supply lines must permit a heavy drain on any service at almost any point in the area, and that service connection changes would be made frequently.

High pressure steam (120 pounds) in a 2.5-inch line, city water in a 4-inch line, gas in a 4-inch line, and compressed air in a 2-inch line are carried most of the way around the area, supported on the lines of columns just below the second-floor level, as shown in Figure 4. Shutoff valves in the loops permit isolation of a section during installation of a new connection without shutting down the entire area. Plugged tees at 16-foot intervals along the loops make it easy to break into the lines for new connections. The hanging platform shown in the illustration is used by the pipefitters. The high location of these service lines, about 20 feet above floor level, keeps them well out of the way of all operations and traffic, but makes the pipefitters' job somewhat difficult. Opinion differs as to whether it would have been better to install the steam and water lines only half as high above floor level.

The primary electric power service to the area is a heavy 208-volt, 3-phase bus, of 2500-ampere capacity, carried all the way around the walls in a grounded metal box below the second-floor level. Heavy connections are made direct from the bus. Load-center boxes fed from the bus are mounted at intervals on the walls, and conduit lines are run from the nearest load center to lighter equipment. In addition, heavy-duty single-phase and three-phase plug receptacles are installed on each column. The general opinion is that the cost of the heavy bus loop has not been justified by experience.

The entire floor area is pitched 0.125-inch to the foot toward floor drains which are located in the centers of each 16 $\times$ 12

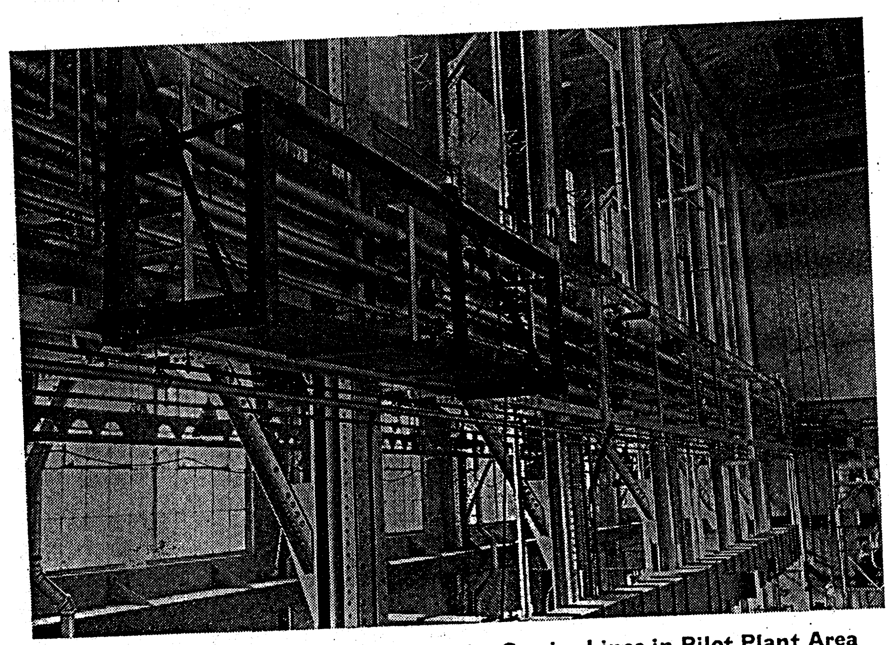


Figure 4. Arrangement of Main Utility Service Lines in Pilot Plant Area

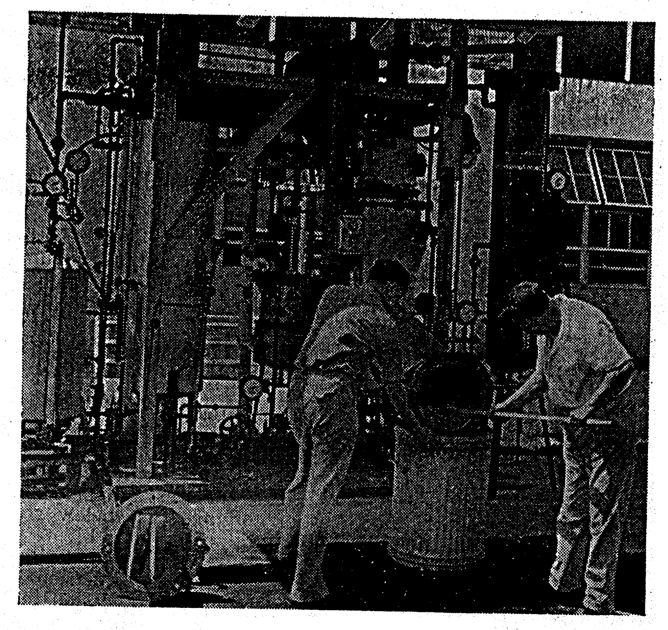


Figure 5. Outdoor Pilot Plant Equipment

Batch oilseed extractor at southern laboratory

foot rectangle except down the center of the room. The drains are provided with removable grating covers flush with the floor level. The pitching of the floor was not accomplished accurately during the pouring of the concrete; consequently water tends to stand in pools in low spots here and there. A slightly greater pitch would have been tolerable, and very careful attention to precise pitching would have paid large dividends in the convenience and comfort of the operating staff.

Drain pipes with plugged branches, located at each column to receive waste water from condensers and the like, have been found very useful. Additional plugged branches on the same drain stacks might well have been located at the balcony levels as well as at the floor level. Steam condensate return lines are located in pitched trenches which run along both side walls below the floor level. The trenches are covered, flush with the floor level, by flat steel plates with nonskid surface pattern. These condensate trenches have been a fruitful source of annoyance, and sometimes of serious trouble, particularly in the western laboratory. Food processing operations have been carried on in this area, and washdowns must be frequent and thorough. The flushing water, carrying waste food particles with it, inevitably has found its way into the condensate trench, which thereupon becomes a nuisance. However, no completely unobjectionable way of handling the condensate from steam-heated kettles, stills, dryers, and similar equipment has come to notice.

The pilot plant area is heated by means of low-pressure steam space heaters suspended below the second-floor balconies along the sides of the room. As originally planned, the only ventilation would have been accomplished by opening windows. In the southern laboratory four motor-driven exhausters have been installed in the east end of the building, one at each floor level, to give one air change in 7 minutes, mainly because operations with volatile solvents are frequently carried on in the area. Two such exhausters, installed in the roof at the western laboratory, give about one air change in 15 minutes; the problem there was mainly the removal of process heat and moisture vapor. Some difficulty has been experienced with maintenance of the gang window operators in several of the laboratories.

Electrical fixtures in the solvent operations area of the southern laboratory are uniformly of the type suitable for Class 1, Group D, hazardous locations. This practice has not been followed in the other laboratories; instead, operations with flammable solvents have been isolated from the main working space. Even though the main pilot plant area in the southern laboratory is carefully safeguarded, such an extrahazardous operation, batch extraction of oilseeds with diethyl ether and other solvents, has been located outdoors (Figure 5).

In an effort to provide the utmost in structural flexibility, the original design included steel-grating balconies at the three elevated floor levels only at the end of the pilot plant area next to the administration wing and only at the second-floor level along both sides of the room. Alternate bays of these side balconies were bolted to the columns, not riveted, so that they could be removed completely. This appears to have been an unnecessary elaboration. In most of the laboratories the steel-grating balconies have been replaced by drained and curbed concrete balcony floors. This change has transformed the balconies into useful working space. Each column was originally provided with bolting plates along two of its four corners, as shown in Figure 6. This idea is useful, both for the quick attachment of temporary staging or platforms at odd heights and for convenient support of equipment such as ejectors and condensers above floor level.

SPECIAL SERVICE EQUIPMENT

Various special service facilities have been installed in the pilot plant areas. Special provisions for dealing with flammable solvents have been mentioned; it is generally agreed, however, that the only fully satisfactory location for such operations is a separate structure or out of doors. Safety equipment, such as fire extinguishers, fire hose with fog nozzles, masks, fire blankets, showers, and protective clothing for workers, is a necessity which is not likely to be overlooked, but the proper location for each of these items deserves careful thought in each new set of circumstances. The eastern laboratory has also made extensive use of color schemes for identifying pipe lines, making control valves

Figure 6. Use of Bolting Plates on Columns

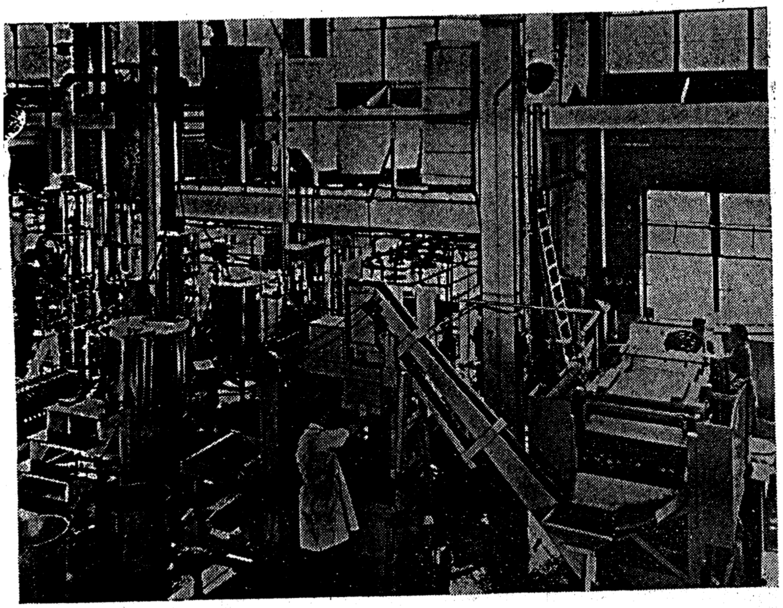


Figure 7. Mechanical Washer, Cider Press, and Vacuum Evaporator for Apple Juice Research, Eastern Laboratory

and switches conspicuous, and marking out pedestrian aisles on the floor.

Although the house steam supply (120-pound) is entirely suitable for most needs, two special installations have been found desirable. In the northern laboratory a small compressor is used to furnish high temperature steam to the platens of molding presses. In the western laboratory certain food processes require substantially odorless steam; this is supplied from a reboiler heated by house steam and fed with city water that is preheated to vigorous boiling in an open vessel.

Facilities for cleanup have been found especially important. Portable vacuum cleaners with long-handled attachments are almost a necessity. Water outlets provided with standard hose thread should be located at numerous places throughout the room, so that hose lines used for cleanup will not encumber the whole floor. In the western laboratory a booster pump supplying 16 gallons of water per minute at a pressure of 500 pounds is permanently connected to a small pipe line serving the two or three places where particularly tough cleaning jobs are located—for example, an experimental spray dryer. There was some nervousness at first about handling this high pressure water by means of rubber hose inside the dryer, but no difficulty has been experienced. Steam-water mixing fixtures are also installed in numerous places where hot water is needed for cleaning equipment. Safety of these fixtures for operators is assured by standard devices.

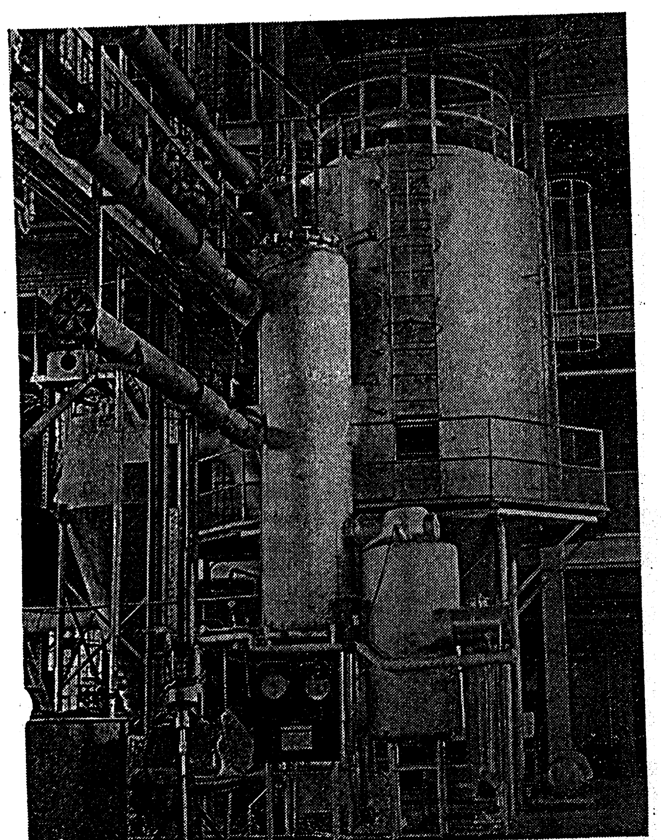


Figure 8. Experimental Spray Dryer, Western Laboratory

EXAMPLES OF INSTALLATIONS

The pilot plant areas of the regional laboratories have been used for several general types of activity, only one of which, according to the accepted definition, should be termed pilot plant operation. This expression means, in recent usage among chemical engineers, the experimental operation of an integrated process, the types of equipment, means of control, and mode of operation being carefully designed to bring out the process characteristics that would appear in full scale commercial operation. "Pilot plant scale" is commonly understood to be in the range of one hundredth to one tenth of "commercial scale," in terms of rate of production. Several examples of true pilot plants in the regional laboratories are described briefly below.

In addition to pilot plant operation, however, the section of the building called by that name has been used even more extensively for large scale preparation work and for various kinds of engineering or technological research.

Large scale preparation of new or improved products is frequently desirable even before it is known whether construction and operation of a pilot plant are justifiable. The laboratory scientist may have made a few hundred grams of a new substance which appears to have market possibilities. Nothing very definite about the size of the market or the price the product might command can be determined until perhaps 50 pounds have been distributed to possible users for trial and comment. The design, construction, and operation of a true pilot plant to carry out the process, however, are too elaborate and expensive an undertaking unless the market prospects look bright. Large scale laboratory preparation, sometimes irreverently known as bath-tub chemistry, is used instead. The laboratory method is simply scaled up. Kettles are used instead of flasks, filter presses instead of funnels. Such important pilot plant considerations as conversion of a batch process to a continuous one, or the design of special equipment in order to reduce operating labor cost, are not pertinent at this stage of the development.

The other kind of activity in the pilot plant area, engineering or technological research, is characterized in part by its dependence on the use of industrial types of equipment. Research on the improvement of cotton fabrics in the southern laboratory, for example, requires the use of typical textile equipment. Investigations on apple juice in the eastern laboratory call for the preparation of relatively large volumes of juice under controlled conditions, and for this purpose the mechanical washer, cider press, and vacuum evaporator seen in Figure 7 are installed in the pilot plant area. Investigation of the fundamentals of spray drying at the western laboratory makes use of a dryer (Figure 8) which, while designed for experimental work, is much too large to go into a standard laboratory. Most of the large scale food processing equipment at the western laboratory is used to prepare the rather large quantities of carefully processed fruits or vegetables that are needed for a wide variety of physical, chemical, and organoleptic evaluations and for long-time storage studies.

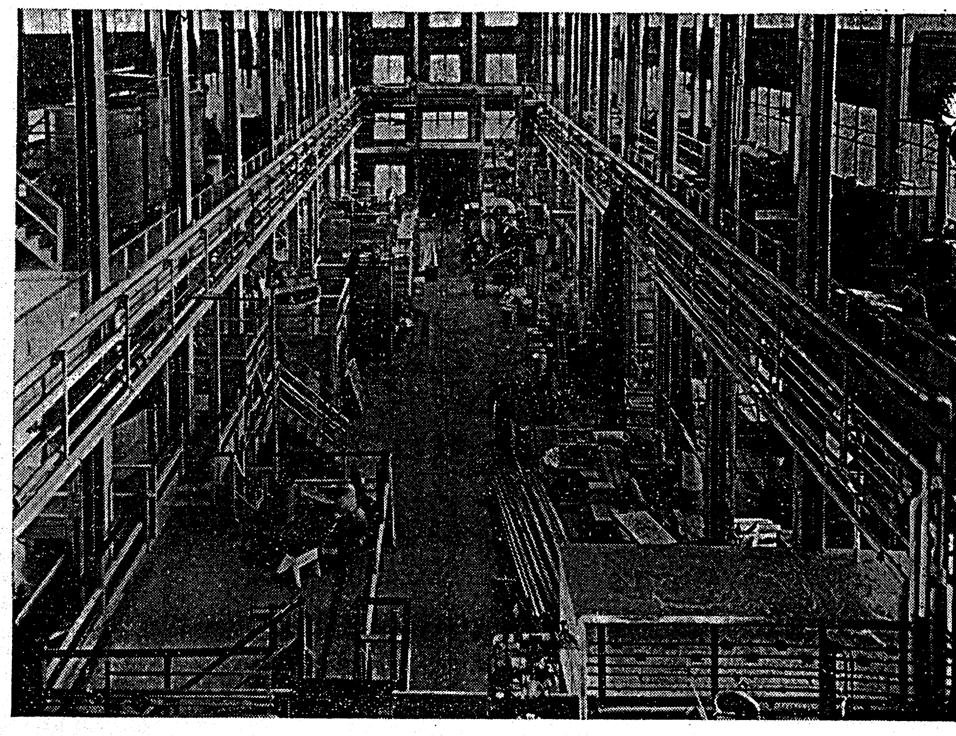


Figure 9. General Pilot Plant Area, Eastern Laboratory

Pilot plant for recovery of kok-saghyz rubber on left

Pilot plant developments, in the more precise meaning of the term, are undertaken only after careful analysis of the commercial prospects of the new process. Important elements in the equipment layout are likely themselves to be experimental, designed specifically to play a key role in the pilot plant. Each of the four regional laboratories has had occasion to install and study true pilot plants. The four examples chosen for illustration show how several different types of plant have been installed successfully and operated in the general pilot plant areas of the laboratories.

Figure 9, a general view of the pilot plant area in the eastern laboratory, shows the equipment used in studying the recovery of natural rubber from the roots of kok-saghyz, or Russian dandelion. Figure 10 is a plant in the southern laboratory used primarily for the drying of sweet potato pulp and starch, but also available for other heating or drying operations. The alcohol pilot plant in the northern laboratory has been described. A less elaborate pilot plant in that laboratory (Figure 11) was designed for studying the production of saccharic acid from dextrose. Figure 12 is a plant in the western laboratory in which the production of low-methoxyl pectin from citrus fruit peel is being investigated.

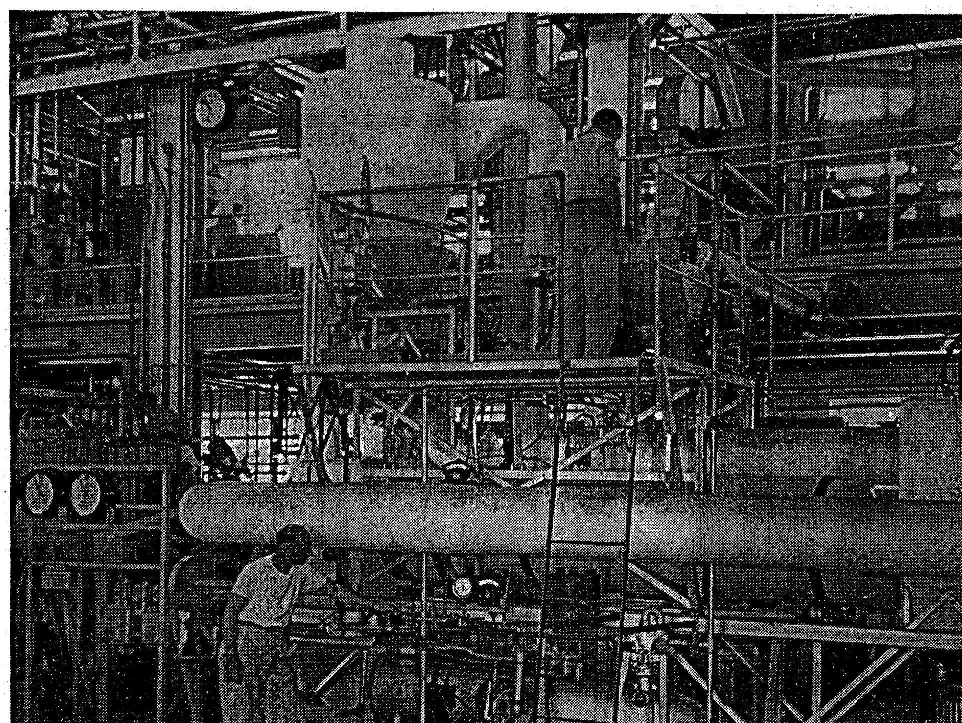


Figure 10. Sweet Potato Starch and Pulp Dryers, Southern Laboratory

PILOT PLANT PERSONNEL AND OPERATION

In each of the regional laboratories from 20 to 30 employees of professional grade, most of them trained chemical engineers, are concerned either constantly or occasionally with experimental operations in the pilot plant area. A locker and shower room, only a few feet away from the pilot plant area, provide a place where these men can clean up and change their clothes. It is also essential to provide them with office space outside the pilot plant area, where they can keep their books and

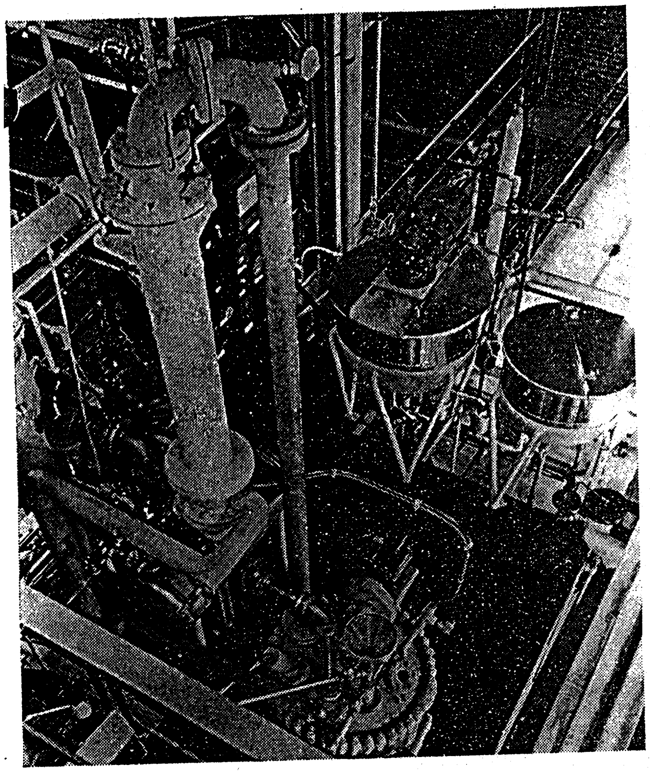


Figure 11. Pilot Plant for Saccharic Acid Production, Northern Laboratory

records and where they can study or write without distraction.

Organization of the large scale research varies in the four laboratories. In all four the general pilot plant area is administered by an engineering and development division. In the northern laboratory a portion of the area containing specialized fiber processing equipment is controlled by the agricultural residues division, and in the southern laboratory the areas containing special textile and other cotton equipment are administered by the cotton processing division and the cotton chemical finishing division.

In the general pilot plant area it has been found desirable to designate one of the professional engineering employees as superintendent. Subprofessional employees and laborers under his direction maintain the equipment and premises in good condition and assist in the routine operation of equipment. Maintenance and emergency repairs are facilitated by keeping small stocks of gaskets, belts, packing, nuts and bolts, and spare parts in chests or racks along the walls. Small tools such as wrenches, pliers, and screwdrivers are kept in chests, lockers, or a small toolroom. The special tools used for assembling or cleaning a special piece of equipment are, if possible, kept in a cabinet adjacent to the equipment. Major maintenance jobs are handled by the skilled craftsmen of the mechanical shops—carpenters, pipefitters, machinists, electricians, welders, and sheet-metal men, who also perform a large part of the fabrication and erection of special equipment. The main stocks of pipe, fittings, sheet metal, lumber, and the like are kept by the shops or in a mehanical storeroom.

A few standard chemical laboratories, capable of accommodating from two to six or eight workers, are located near the pilot plant area. In some cases there is a considerable volume of laboratory work such as preparation and standardization of reagents, calibration of instruments, and routine analyses of products to be carried out along with the pilot plant operation. Some small scale engineering research is conducted more conveniently in a laboratory room than in the pilot plant area.

Not enough general storage space was provided in the design of the regional laboratories. Although the condition is gradually being remedied by new construction, the shortage of good storage space has brought a succession of other evils in its train. Inactive equipment in the pilot plant obstructs working space, may be damaged by surrounding activities, leads to undue crowding of active equipment, and is a breeder of slovenly housekeeping. At least 0.5 square foot of proper storage area, under cover, should be provided for every square foot of active pilot plant area.

SUMMARY

In general, the pilot plant areas for the four regional laboratories have been highly satisfactory. The facilities provided are versatile and the space devoted to them seems to have been well proportioned to the size of the job to be done. A considerable part of the 45-foot headroom is unnecessary; more floor area with 22-foot headroom would have been better. This alteration, and the addition of storage space for inactive equipment, would increase the usefulness of the space materially. Some types of technological research have such specialized requirements that they should be housed in specially designed space, separate from the general pilot plant area. The latter is best adapted to engineering research on unit operations, to large scale chemical preparation work, and to the pilot plant development of chemical processes.

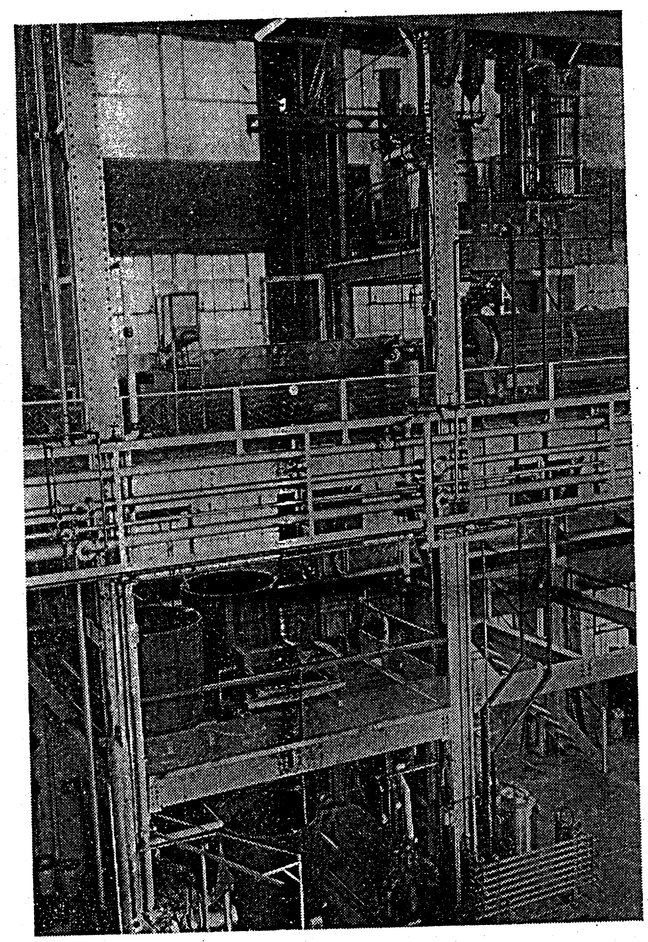


Figure 12. Pilot Plant for Production of Low-Methoxyl Pectin from Citrus Fruit Peel, Western Laboratory